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U.S. DEPARTMENT OF COMMERCE

TRANSMIT/ROUTE SLIP

DATE

30 Aug 00

NAME	BUILDING, ROOM OR REFERENCE NO.	TAKE ACTION BELOW	INITIALS AND DATE
Don Blusch		1	31 Aug 00 DJO
Col Himnant		2	7st 1 Sep 00
Stan Schneider / Steve Mango		3	=
Steve Mango	O.K. to release from my review.	3	SAM 9/1/00
(small corrections remarked in blue)			

ACTION ITEMS

1. APPROVAL/SIGNATURE
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3. RECOMMENDATION OR COMMENT
4. RETURN WITH MORE DETAILS
5. INVESTIGATE AND REPORT
6. NOTE AND SEE ME
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9. YOUR INFORMATION
10. PER OUR CONVERSATION
11. AS REQUESTED
12. NECESSARY ACTION
13. CIRCULATE AMONG STAFF
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COMMENTS

ITT paper - concurrence that paper is okay to release.

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FROM (Name)	BUILDING, ROOM OR REFERENCE NO.	CODE AND EXTENSION
Elisa		142

SEP 1 2000

MEMORANDUM FOR: SAF/PAS
1690 Air Force Pentagon - 5D227
Washington DC 20330-1690

FROM: Francis G. Hinnant, Col, USAF
Associate Director of Acquisition
NPOESS Integrated Program Office
8455 Colesville Rd, Suite 1450
Silver Spring, MD 20910

SUBJECT: Cross-Track Infrared Sounder (CrIS) ITOV Presentation

Enclosed are the required ten (10) copies of the subject presentation. This presentation will be given at the 11th International TIROS Operational Vehicle Sounder (ITOVS) conference to be held in Budapest, Hungary from 19-25 Sep 00. This conference is sponsored by NASA, NESDIS, EUMETSAT, the World Meteorological Organization, the Australian Bureau of Meteorology, and METEO-France. Mr. Joseph Predina, ITT Industries, will present this paper.

The program office has reviewed the information and found it appropriate for public disclosure without change.

Point of contact on this matter is Mr. Hal Bloom, NPOESS IPO/ADA at 301-427-2084 (Ext. 170).

cc: ADA (E. Kang)

Attachment: Presentation—10 copies

THE CROSSTRACK INFRARED SOUNDER (CrIS): DESIGN AND PERFORMANCE

Joseph P. Predina and Ronald J. Glumb
ITT Industries, Aerospace / Communications Division
Fort Wayne, Indiana USA

1. INTRODUCTION

The Crosstrack Infrared Sounder (CrIS) is one of the primary sensors within the NPOESS system. Its mission is to collect upwelling infrared spectra at very high spectral resolution, and with excellent precision. This data is then merged with microwave data from other sensors on the NPOESS platform to construct highly accurate temperature, moisture, and pressure profiles of the earth's atmosphere. Collectively, the CrIS and microwave sensors are referred to as the CrIMSS (Crosstrack Infrared and Microwave Sounding Suite). The profiles produced by this suite are a primary input to numerical weather forecast models, and their improved accuracy offer the promise of revolutionary improvements in forecast accuracy on a global basis.
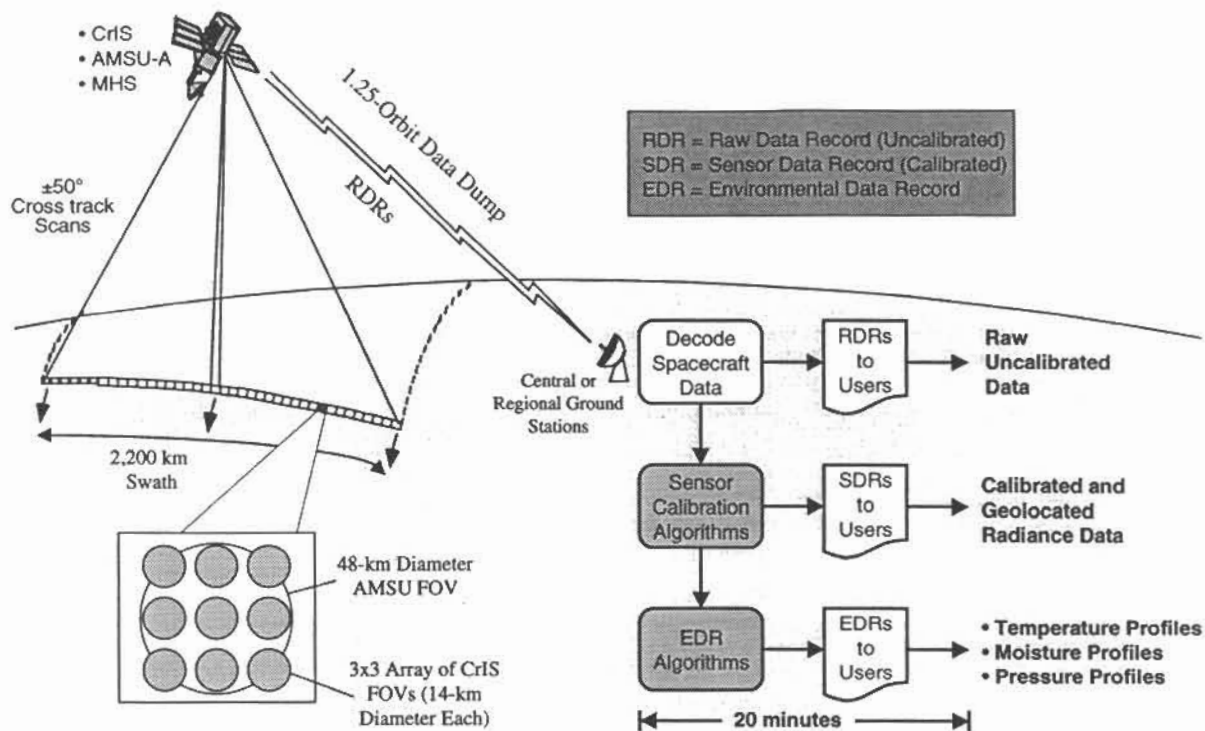
In 1997, design work began on the CrIS system, as part of a Phase 1 study with the NPOESS Integrated Program Office (IPO). The objective of this study program was to examine numerous sensor configurations to arrive at a "best value" approach, develop a complete design for the CrIS sensor and algorithms, and conduct numerous hardware and software risk-reduction demonstrations to address specific CrIS risk areas. The Phase 2 program is now underway, and is headed towards delivery of a flight sensor by 2004 to support a first flight on the NPOESS Preparatory Program demonstration satellite in the 2006 timeframe.

The purpose of this paper is to describe the design of the CrIS system (with an emphasis on the algorithm segment), and to summarize the top-level performance parameters expected of CrIS when combined with CrIMSS.

2. CrIS SYSTEM OVERVIEW

CrIS is part of the overall crosstrack scanning CrIMSS suite (Cross-track Infrared and Microwave Sounding Suite), which is one of the sensor suites onboard the NPOESS satellite. CrIMSS was originally to be composed of CrIS plus the AMSU-A and MHS microwave instruments, but current plans call for these microwave instruments to be replaced by the Advanced Technology Microwave Sounder (ATMS).

The NPOESSS satellites operate in a polar orbit at a nominal altitude of 833 km. During typical operations, CrIS will collect radiance data over an extended period of time (typically 1.25 orbit), then downlink this data to central or regional terminals where the data is calibrated and converted into science products. Three types of CrIS data products are generated in this process; Raw Data Records (RDRs), Sensor Data Records (SDR's) and Environmental Data Records (EDR's).

Figure 1 Overall Architecture of the CrIS System

RDRs are unprocessed and uncalibrated raw sensor data (also commonly referred to as Level 0 data products) supplemented with geo-location data, calibration parameters and other data necessary for the mission. The primary component of CrIS RDRs are interferograms collected from 27 infrared detectors that cover 3 IR bands and 9 Fields of View (FOV). SDRs are processed RDRs, converted to spectra, spectrally calibrated, radiometrically calibrated and tagged with a geolocation (comparable to Level 1 data products). EDRs are the resultant profiles of temperature, moisture, and pressure that are produced by passing the CrIS and microwave sensor SDRs through EDR algorithms (to produce Level 2 data products). All of these data products will be available 20 minutes following the downlink data dump.

The 3 x 3 array of 14 km diameter CrIS FOV's undergoes a rotation and a growth to 49 x 31 km ellipses as the scan progresses away from nadir. Figure 2 illustrates the pattern of FOV's generated during three sweeps of the CrIS sensor from nadir to edge of scan and compares this with the AMSU-A and MHS FOV patterns.
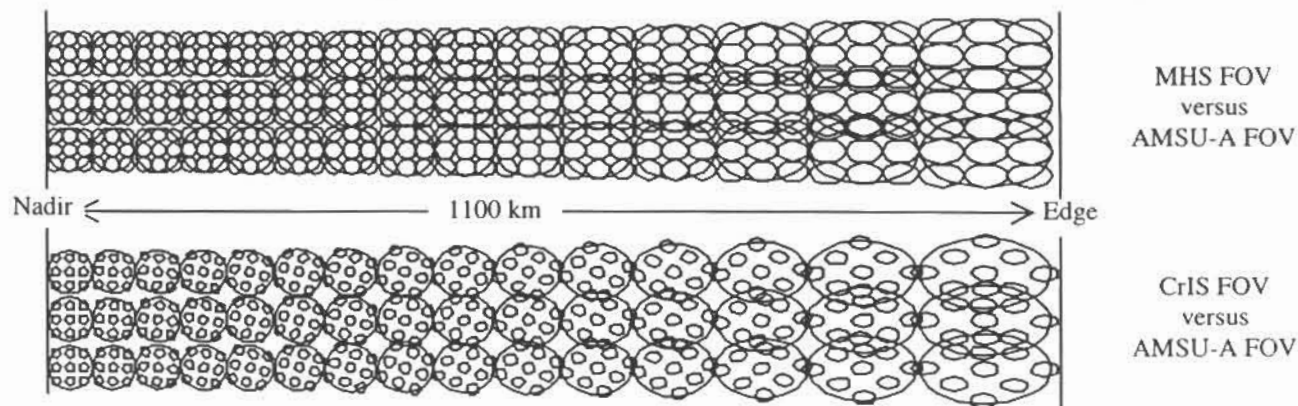
Figure 2 CrIS FOVs Rotate Relative to MHS FOVs as Scan Progresses from Nadir to Edge

3. CrIS SENSOR AND THE GENERATION OF RDRs

The performance of the CrIS sensor is a significant leap forward when compared to existing operational sounders. Figure 3 summarizes the key performance parameters of the CrIS sensor currently under development at ITT Industries. Most notable is the noise equivalent radiance and noise equivalent temperature achieved in the key LW and MW bands. Radiometric uncertainty levels are also quite good.

Sensor Parameter	Guaranteed Value	Sensor Parameter	Guaranteed Value
LWIR Band	650-1095 cm^{-1}	FOV Motion (Jitter)	< 50 urad / axis
MWIR Band	1210-1750 cm^{-1}	Mapping Accuracy	< 1.45 km
SWIR Band	2155-2550 cm^{-1}	Absolute Radiometric Uncertainty	< 0.45% (LWIR) < 0.6% (MWIR) < 0.8% (SWIR)
LWIR Spectral Resolution	< 0.625 cm^{-1}		
MWIR Spectral Resolution	< 1.25 cm^{-1}		
SWIR Spectral Resolution	< 2.5 cm^{-1}	Radiometric Stability	< 0.4% (LWIR) < 0.5% (MWIR) < 0.65% (SWIR)
Number of FOVs	3 x 3		
FOV Diameter (Round)	14 km	Spectral Shift Errors	< 5 ppm

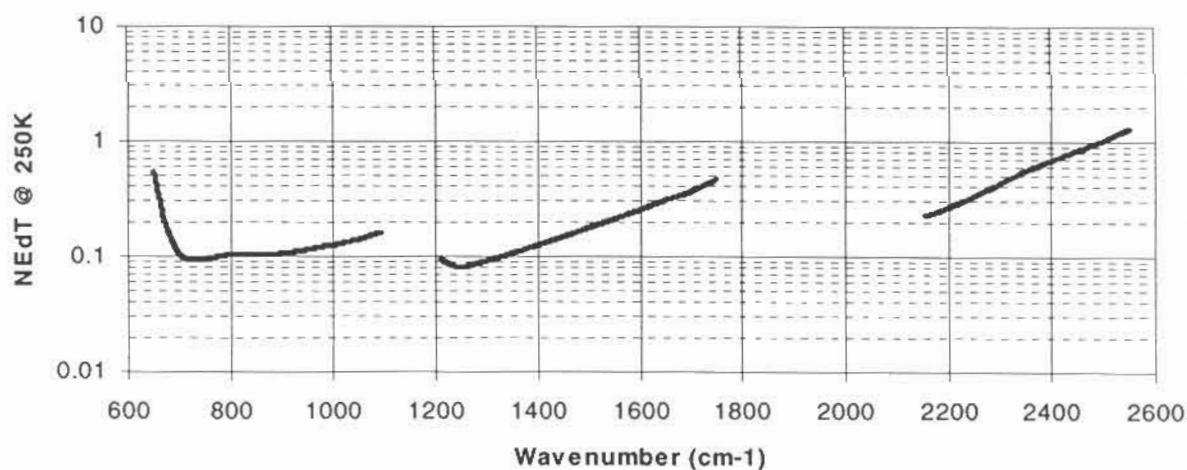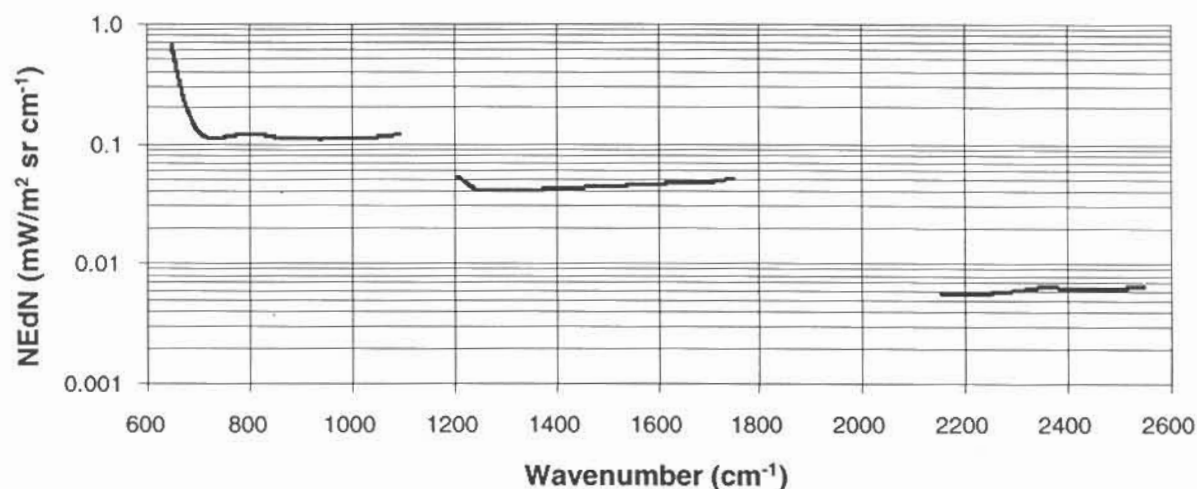**Figure 3 Guaranteed Performance Profiles of the NPOESS CrIS Sensor**

- Large 8 cm Clear Aperture
- Three Spectral Bands
- 3x3 FOVs at 14 km Diameter
- Photovoltaic Detectors in All 3 Bands
- 4-Stage Passive Detector Cooler
- Plane-Mirror Interferometer With DA
- Internal Spectral Calibration
- Deep-Cavity Internal Calibration Target
- Onboard Signal Processing Electronics
- Highly Stable Sensor Structure
- Modular Construction
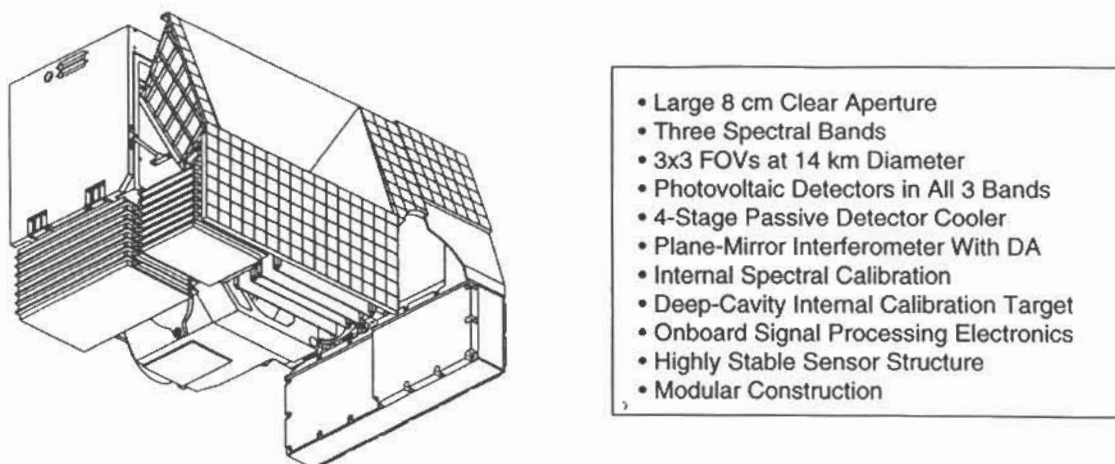
Figure 4 CrIS Sensor and Primary Design Features

Figure 4 shows the CrIS sensor and some of the features that are responsible for the performance achieved in Figure 3. The raw data records assembled by the CrIS sensor are the result of on-board signal processing as illustrated in Figure 5. The majority of this signal processing supports lossless data rate reduction to minimize storage and transmission requirements for the satellite. Possible future enhancements to the system include expansion of the 3 x 3 detector arrays to larger arrays such as 4 x 4 or 6 x 6. The hardware architecture of the CrIS sensor was purposely configured to accommodate such a change as the technology matures.
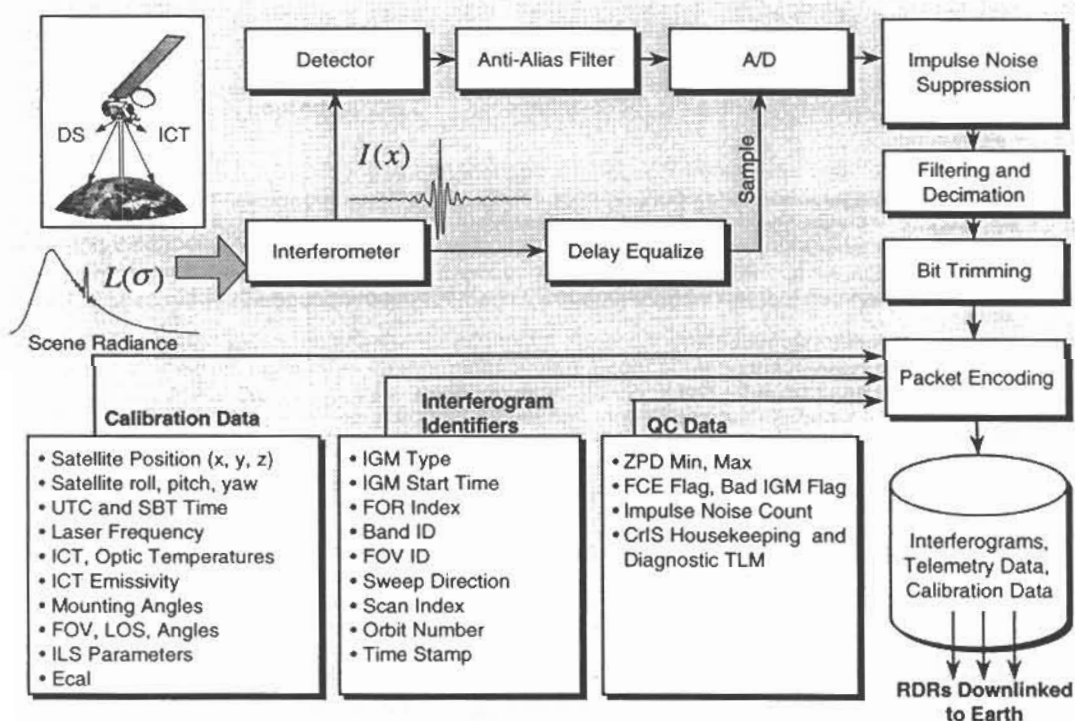
Figure 5 CrIS On-board Signal Processing Assembles RDRs for Subsequent Transmission

4. SDR ALGORITHM DESIGN

The purpose of the SDR algorithm is to convert raw uncalibrated sensor data (RDRs) into fully-calibrated Sensor Data Records (SDRs). The SDR algorithms perform geolocation, conversion of interferograms to spectral data, radiometric calibration, and spectral calibration of the raw data. This includes mapping the spectral centers of each "bin" of the SDR to the exact spectral channels used by the EDR algorithms.

The CrIS SDR algorithm is heavily based on previous algorithms developed by Bomem for other interferometric programs such as MIPAS[9]. These algorithms have already been optimized to operate efficiently and quickly (to meet NPOESS timeliness requirements), and with high levels of accuracy. For example, the process used to remove sensor background radiance, correct for phase dispersions, and perform radiometric calibration was first developed jointly by Bomem and the University of Wisconsin as part of the HIS program[10], and were later enhanced on other programs. The CrIS calibration algorithms were also recently demonstrated during the CrIS Phase 1 program which ended in May of 1999.

The CrIS SDR algorithms produce calibrated and geolocated radiance measurements on a fixed wave number grid and with identical ILS for any spectral channel within the band regardless of the FOV processed and regardless of the sensor originating the data. Table 1 summarizes the spectral parameters to which the radiance measurements are aligned.

Band	Wavenumber Range (cm^{-1})	Resolution $(1/2L)$ (cm^{-1})	Spectral Channels per FOV	1st Channel Center (cm^{-1})	Last Channel Center (cm^{-1})
LW	650 - 1095	0.625	712	650.3125	1094.6875
MW	1210 - 1750	1.25	412	1210.625	1749.375
SW	2155 - 2550	2.5	158	2156.25	2548.75

Table 1 CrIS Level 2 Data is Processed (Remapped) to Same Channel Centers for All CrIS Sensors Regardless of Hardware Differences Between Each Individual Sensor

The CrIS SDR algorithm includes several new features that advanced the state-of-the-art. Of most significance is a routine that corrects for spectral variations of the sensor Instrument Line Shape (ILS). Any slight ILS variation between the 9 FOVs and between any set of CrIS sensors is removed by this process. Furthermore, regardless of the actual shape of the ILS originating from the sensor, all distortions are removed by SDR algorithm processing to yield an ideal unapodized ILS (or other user designated ILS shape such as Hamning or Blackman). This simplifies the EDR algorithm design by allowing the construction of a single radiance forward model that operates with all sensors and FOVs within the sensor. The normalization of the ILS as described above also enables fast execution of EDR algorithms that contrast adjacent FOVs. Since this feature eliminates the need to "tune" the EDR algorithm to the ILS of individual sensors, then this allows

science algorithm development independent from sensor hardware variations. This may be particularly important if other CrIS data users would like to implement their own EDR algorithms.

The SDR algorithms will output fully-calibrated SDR data that can be directly used by other users without having to correct for other unique signatures of the sensor hardware. Spectral accuracy is 5 ppm using a patented laser metrology calibration method used on the CrIS sensor. The spectral knowledge provided by the CrIS sensor and downlinked in RDRs can then used by the SDR algorithm to map radiance measurements onto the fixed channel centers defined in Table 1 with the same 5 ppm accuracy.

Figure 6 shows an overview of the SDR algorithm process. The process is repeated for each of the 27 CrIS IR detectors and for each sweep direction of the CrIS interferometer. The calibration of radiance as depicted in Figure 6 follows the formulation initially developed on the HIS program in 1988; a joint effort of Bomem and the University of Wisconsin.
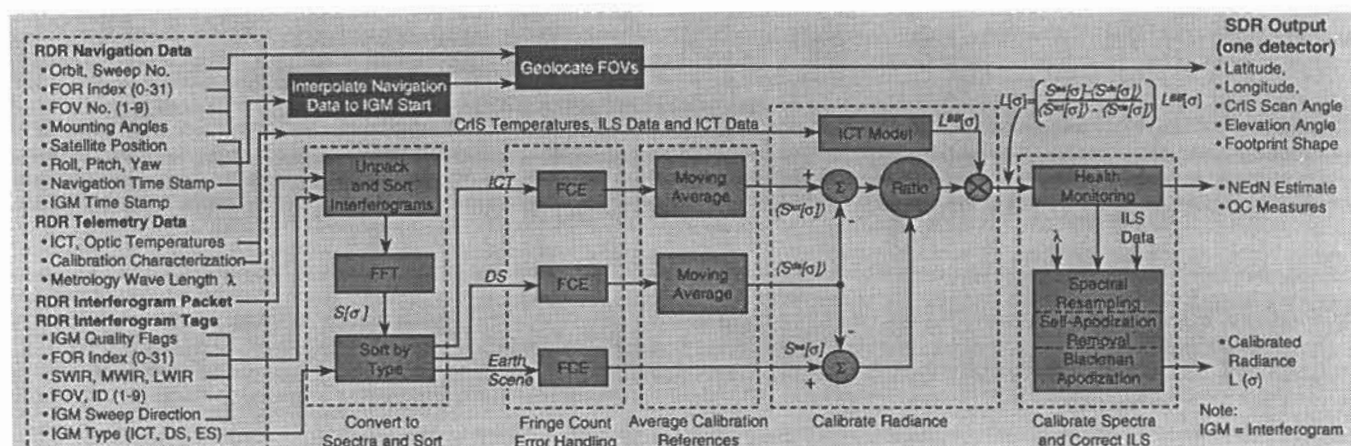

Figure 6 SDR Algorithm Flow

Another significant feature of the CrIS SDR algorithm approach is that all data needed to calibrate the CrIS sensor is contained within the CrIS RDRs. No sensor unique calibration handbooks will need to be distributed to users because all calibration parameters and characterizations are broadcast in the RDR data stream from the satellite. In addition, quality control features within the SDR algorithm indicate the quality of each radiance measurements within an FOV, identify certain types of errors and in some cases correct for them.

ITT and Bomem are currently developing "science code" for the SDR algorithms. The science code will be completed by CDR (12/20/01), after which the development of the actual operational code becomes the responsibility of the NPOESS Total System Performance Responsibility (TSPR) contractor. Preliminary SDR science code has been developed, along with an Algorithm Theoretical Basis Document (ATBD)[11].

Table 2 illustrates various parameter drifts whose effects are normally removed by a tuning process of the operational algorithms. Note that virtually all of the hardware unique variations typically removed by tuning are primarily accomplished through the SDR algorithms in the NPOESS CrIS system.

Parameter	SDR	EDR	Tuning Method	Time Constant
Background Radiance Offset	X		Measure space look radiance, average 30, subtract offset	Minutes
Radiometric Gain	X		Measure space look and ICT radiance, average 30, subtract offset, scale instrument counts to accurate ICT radiance model	Minutes
Optical and Electrical Phase Dispersion	X		Automatically cancelled in calibration process	Hours
Calibration Target Parameters	X		Emissivity and temperature data broadcast in RDRs. ICT algorithm model computes radiance. Vicarious ground calibration checks allow emissivity table updates of the ICT	1 to 7 Years
Detector Nonlinearity			No correction needed. CrIS using <0.1% nonlinear PV detectors in all three bands	N/A
ESD Discharge or Detector SEU			No correction needed in algorithms. Impulse noise detected and clipped to lower level in CrIS sensor, low probability of occurrence per measurement	N/A
CrIS ILS FWHM	X		Ground characterization tests for each FOV combined with sensor self apodization models combine with an SDR algorithm removal technique. Sensor dynamically aligned (DA) optics maintains stable characteristic over 7 years	7 Years
CrIS ILS Sidelobe	X		Same as above	7 Years
CrIS Spectral Reference	X		CrIS laser metrology wavelength knowledge calibrated against neon gas standard once per orbit. 5 ppm knowledge used by algorithms to remap sensor channels to desired center and correct ILS	5 Hours
CrIS Scan Polarization	X		Pre-launch scan mirror characterization, correct offset and gain vs scan angle. Expect negligible polarization effect prior to correction (unpolarized IR scene and Epner gold electroplated scan mirror always viewed at 45 deg)	Years or no correction likely
CrIS Geolocation Parameter Shifts	X		CrIS mounting angles, scan encoder offsets, step/settle error and S/C position, roll, pitch, yaw contained in RDR's for each FOR step. Algorithm computes sea level latitude and longitude at all FOV centers	Each Step
CrIS NEdN Variation (+ EMI and spurious)	X	X	Real time bin by bin SDR algorithm estimate. EDR adjusts covariance error matrix and Quality Control (QC) thresholds	Minutes to hours
Interferogram ZPD Uncertainty	X		Fringe count errors removed prior to calibration. Calibration removes remaining phase shift errors induced by ZPD shifts	Minutes
CrIS Band to Band Co-registration			No tuning needed. Coregistration maintained by hardware design	7 Years
MHS to CrIS Co-registration		X	CrIS FOR rotation vs MHS. Simultaneous MW/IR retrieval uses weighted average of nearest neighbor MHS FOVs to CrIS FOV	7 Years
Trace gas and CO_2 Variability		X	Seasonal EDR algorithm tables by latitude correct for concentrations	Years
Scene FOR Inhomogeneity		X	Surface maps, 1.5 km geolocation, cloud clearing tests, precipitation tests, MW brightness tests for (snow, ice, land, ocean, coastal). FOV clustering	Each Step
LBL Spectroscopic		X	Forward model updates, validation campaigns	Years
RTA Fitting Error		X	Updated optical depth tables vs temperature, scan angle correction	Years

Table 2 Most Tuning is Autonomous and Transparent to EDR Algorithms Yielding a Simple and Easy to Maintain System Operationally

5. EDR ALGORITHM DESIGN

The purpose of the EDR algorithm is to use the calibrated CrIS sensor data (SDRs) in conjunction with other external data, to estimate vertical profiles of temperature, moisture, and pressure in the earth's atmosphere, and to produce the corresponding EDRs. In essence, the EDR algorithm operates by determining which combinations of atmospheric temperature, moisture and pressure produce the best fit of radiances observed by CrIS, AMSU-A, and MHS.

The Advanced Technology Microwave Sounder (ATMS) will eventually replace AMSU-A and MHS and will possess its own calibration algorithms that develop SDR's for ATMS. The NPOESS CMIS sensor also plays a role in the system. The CMISS EDR provides the high altitude temperature profile coverage above 0.5 mBar and is merged with the CRIMSS EDR as illustrated in Figure 7.
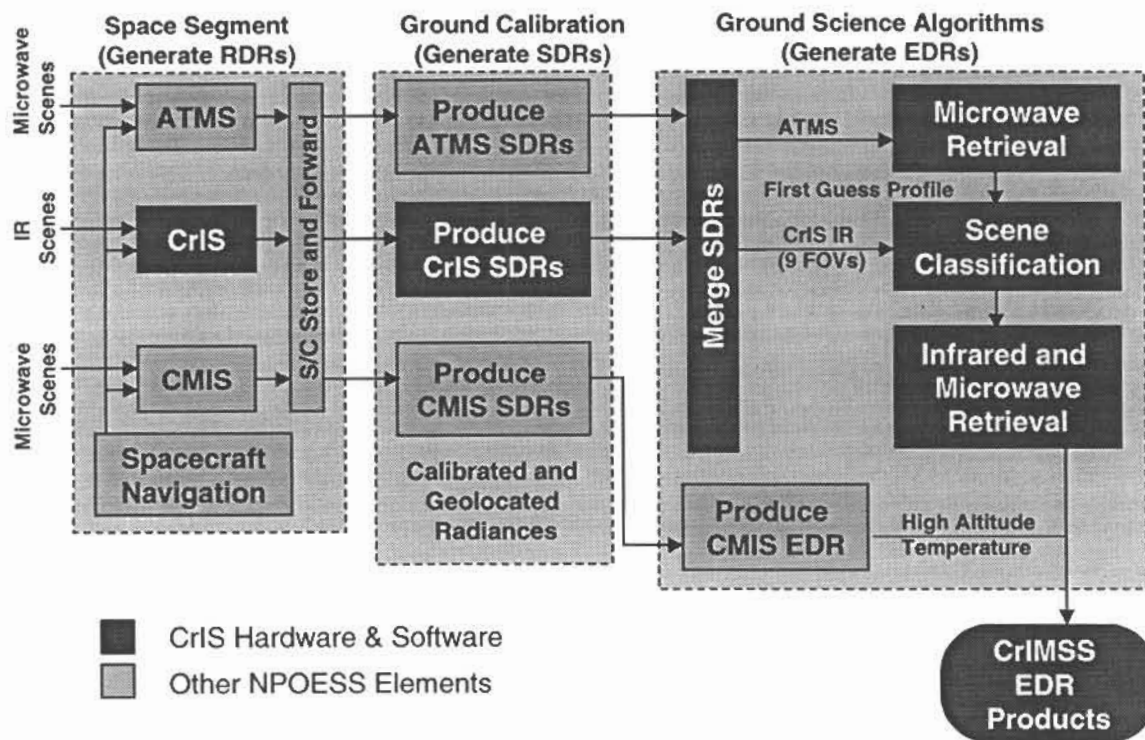
Figure 7 Production of CrIMSS Temperature, Moisture and Pressure Profile EDR Products

The detailed EDR algorithm processing is accomplished in six stages as illustrated in Figure 8. Initialization of the code is accomplished once at startup using static databases. No external dynamic databases are required except for an NWP forecast of surface pressure.

The pre-processing merges CrIS, AMSU-A. and MHS SDR's for each 3x3 set of CrIS FOVs. Numerical Weather Prediction (NWP) data updated every 6 hours is interpolated in time and space to provide a surface pressure first guess that is corrected for elevation of each CrIS FOV. Pre-processing also rejects FOVs

containing heavy precipitation, and discriminates between land, snow, ice, and ocean scenes using microwave radiances and geolocation information in order to properly set surface emissivity constraints.

A microwave retrieval using a single global climatology profile as a first guess is the next step. A sufficiently fast and accurate quadratic regression is used to perform the first retrieval. Subsequent iterations using a physical retrieval follow until a good initial estimate of the temperature and moisture profiles is provided by the microwave sensor segment.
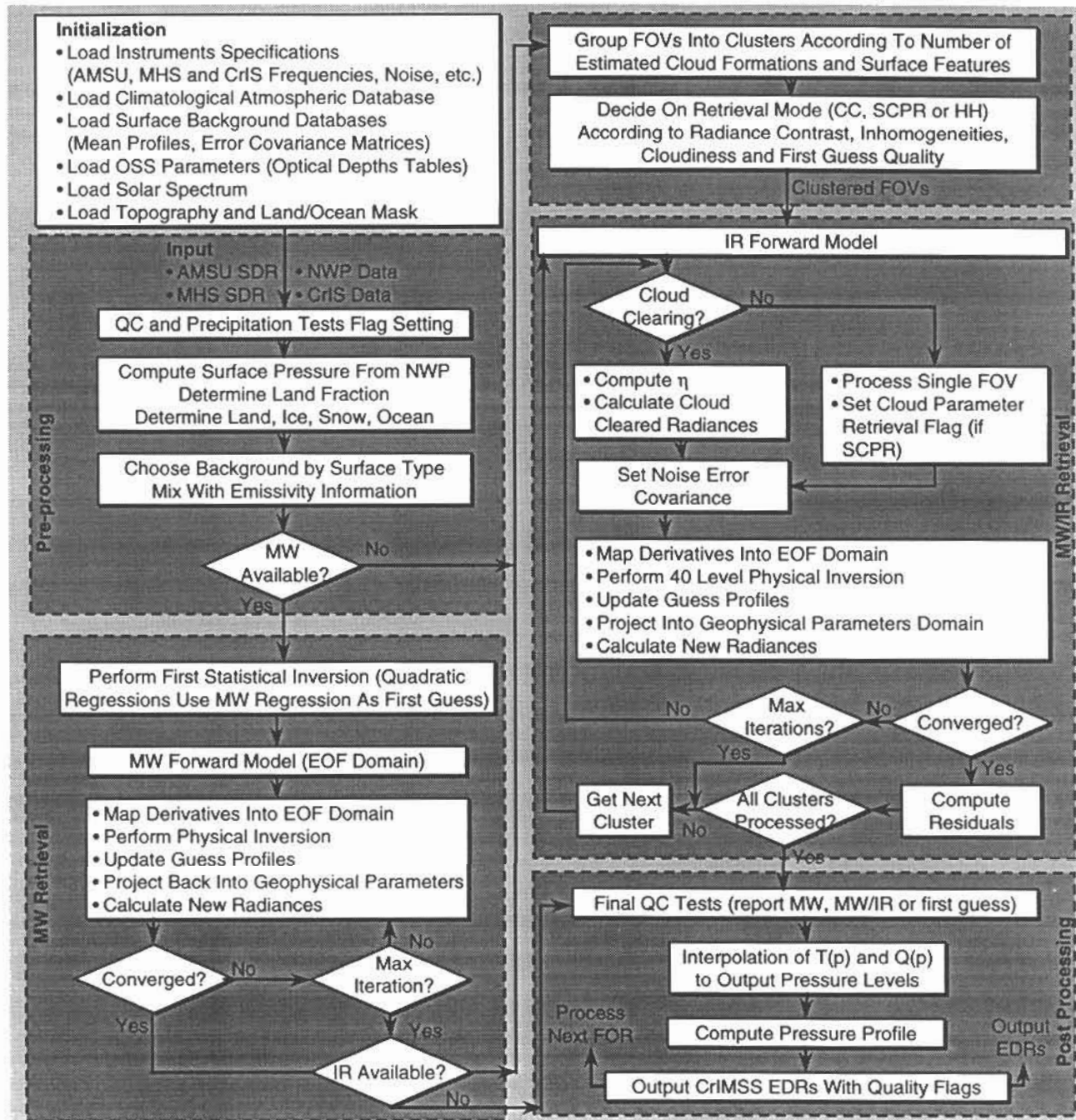
Initialization
- Load Instruments Specifications (AMSU, MHS and CrIS Frequencies, Noise, etc.)
- Load Climatological Atmospheric Database
- Load Surface Background Databases (Mean Profiles, Error Covariance Matrices)
- Load OSS Parameters (Optical Depths Tables)
- Load Solar Spectrum
- Load Topography and Land/Ocean Mask

Input
- AMSU SDR • NWP Data
- MHS SDR • CrIS Data

Pre-processing

QC and Precipitation Tests Flag Setting

Compute Surface Pressure From NWP Determine Land Fraction Determine Land, Ice, Snow, Ocean

Choose Background by Surface Type Mix With Emissivity Information

MW Available? — No / Yes

MW Retrieval

Perform First Statistical Inversion (Quadratic Regressions Use MW Regression As First Guess)

MW Forward Model (EOF Domain)

- Map Derivatives Into EOF Domain
- Perform Physical Inversion
- Update Guess Profiles
- Project Back Into Geophysical Parameters
- Calculate New Radiances

Converged? — No → Max Iteration? — No / Yes

Yes

IR Available? — No

Group FOVs Into Clusters According To Number of Estimated Cloud Formations and Surface Features

Decide On Retrieval Mode (CC, SCPR or HH) According to Radiance Contrast, Inhomogeneities, Cloudiness and First Guess Quality

Clustered FOVs

MW/IR Retrieval

IR Forward Model

Cloud Clearing? — No / Yes

- Compute η
- Calculate Cloud Cleared Radiances

- Process Single FOV
- Set Cloud Parameter Retrieval Flag (if SCPR)

Set Noise Error Covariance

- Map Derivatives Into EOF Domain
- Perform 40 Level Physical Inversion
- Update Guess Profiles
- Project Into Geophysical Parameters Domain
- Calculate New Radiances

Max Iterations? — No / Yes — Converged? — No / Yes

Get Next Cluster — All Clusters Processed? — No / Yes — Compute Residuals

Post Processing

Final QC Tests (report MW, MW/IR or first guess)

Interpolation of T(p) and Q(p) to Output Pressure Levels

Process Next FOR

Compute Pressure Profile

Output EDRs

Output CrIMSS EDRs With Quality Flags

Figure 8 EDR Algorithm Processing Flow

This is then followed by scene classification, in which the nine CrIS FOVs are classified and grouped into clusters in a way to maximize the number of high-quality retrievals. This clustering algorithm is based on

similarity of elevation, surface types, number of cloud formations, and maximizing cloud-induced radiance contrast between clustered FOVs so that cloud clearing algorithms can perform optimally. This process is aided by a unique algorithm developed at Atmospheric Environmental Research Inc. that determines the number of cloud formations present in a FOR and then selects the proper number of FOVs for clustering.

The next step is a combined microwave and IR retrieval using a very fast Optimum Spectral Sampling (OSS) forward radiance model having 40 atmospheric layers. OSS is another development of Atmospheric Environmental Research Inc. which has demonstrated execution speeds 20 times faster than any other fast RTA models provided by the government for benchmarking. A cloud clearing algorithm similar to that developed on the AIRS[12] program provides sounding in partly cloudy conditions where none of the FOVs are cloud free. The MW/IR retrieval is a nonlinear inversion using a modified Gauss-Newton iterative procedure for faster convergence and better stability. The algorithm code developed thus far can achieve similar retrieval performance using only 300 channels from the full 1302 CrIS IR channels available. Thus, execution speed can be dramatically improved with virtually no penalty in performance by optimally selecting which channels to process.

Empirical Orthogonal Functions (EOF) (often referred to as eigenvectors or super channels elsewhere in the literature) are also exploited to improve execution speed and better stabilized the retrieval. The CrIMSS EDR algorithms map the retrieval into 15 temperature, 9 moisture and 1 ozone set of EOFs. Accuracy of the inversion is improved by also retrieving surface temperature, surface pressure, 6 microwave emissivities, six IR emissivities and a SWIR solar reflectance. This set of retrieved parameters has produced a very good balance of accuracy, speed and stability.

Throughout the retrieval process, quality control flags ensure robust operation with graceful degradation. Final post-processing computes a the temperature, moisture and pressure profile while also applying quality control tests to assess the goodness of the retrieval. These quality control measures assess whether the best report is obtained by using the combined MW/IR retrieval, the MW only retrieval or the climatology first guess.

"Science code" for the CrIS EDR algorithm is being developed by the Atmospheric Environmental Research (AER) Inc. and is scheduled for completion prior to the CrIS critical design review on 12/20/01. Afterwards, the development of the actual operational code becomes the responsibility of the NPOESS Total System Performance Responsibility (TSPR) contractor. Preliminary EDR science code has been developed, along with an Algorithm Theoretical Basis Document (ATBD)[11]. Enhancements to the current set of EDR algorithms for the purpose of improving performance further are also being considered as part of the EDR development process through CDR.

6. EDR-LEVEL PERFORMANCE

The combination of the CrIS sensor and SDR/EDR algorithms described above yields EDR performance that establishes a new benchmark for meteorological sounders. Figure 9 summarizes the expected on-orbit performance of the CrIS system for each of its three primary EDRs: temperature, moisture, and pressure. These results are based on simulations that model the CrIS performance under a wide range of conditions, including all types of seasonal, terrain, and cloud conditions. The sensor's radiometric noise and radiometric bias errors have been factored into these results. Typical CrIS performance is averaged over the entire earth, and over a full year of operation (i.e., different seasonal conditions). Performance under clouded conditions is based on statistical distributions for cloud type, altitude, and cloud fraction developed from on-orbit data collected under the CHANCES program[13] and from the Univeristy of Wisconsin HIRS climatology evaluation[14].

The graphs in Figure 9 also show lines labeled "Threshold" which indicate the minimum requirements set for CrIS by the government. In all cases, the expected CrIS performance exceeds government expectations. The results show that CrIS performance is somewhat dependent on altitude (e.g., temperature retrieval accuracy tends to fall off slowly with increasing altitude).

The graphs in Figure 9 represent CrIS performance for conditions in which the 3x3 field of regard (FOR) of the CrIS sensor are covered by 50% cloud or less. Performance for cases of higher cloudcover is slightly inferior with a greater reliance on the microwave segment when the cloud fraction becomes too large.
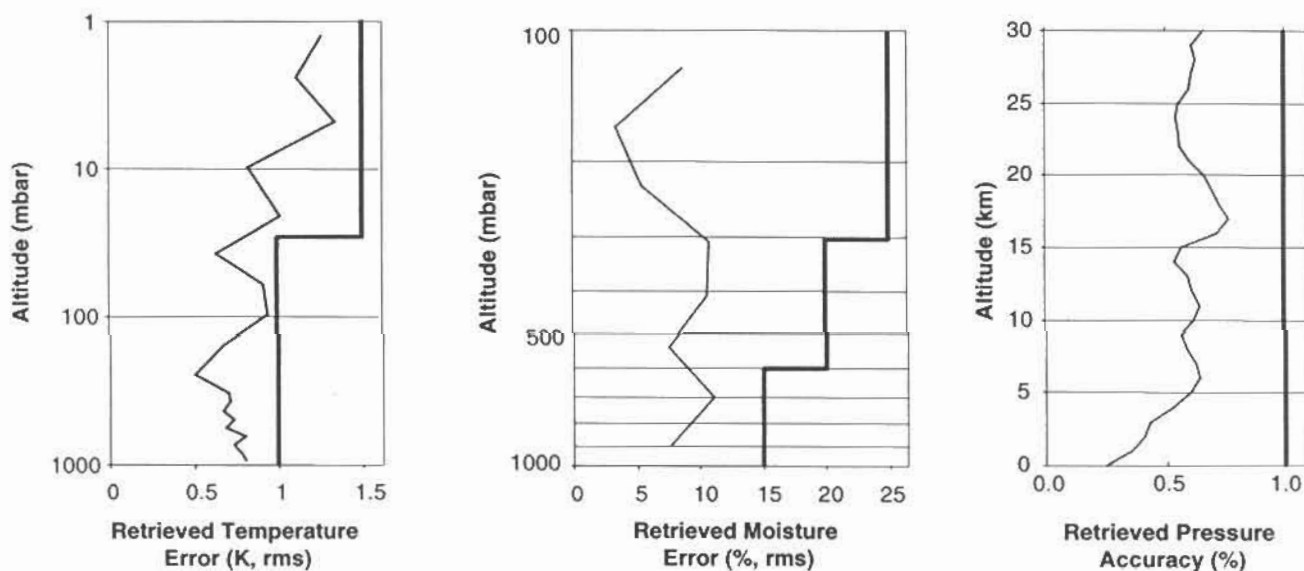
Figure 9. Expected CrIS On-Orbit EDR Performance When Using a Global Ensemble of 48 km x 48 km FORs Having Less Than 50 percent Cloud Fraction

CrIS performance can also be estimated for a variety of individual conditions. Figure 10 and 11 shows a sampling of results for many different types of seasonal, terrain, and cloud conditions. The vertical scale on these plots is a value called "threshold margin", which indicates how much better the CrIS performance level is when compared to minimum requirements established by the government.

In these plots, 0% on the vertical axis represents the minimum performance required. Objective-level performance is indicated by the solid line and represents aggressive performance goals desired by the government. CrIS performance is exceptional across the range, coming quite close to aggressive performance goals under many conditions.
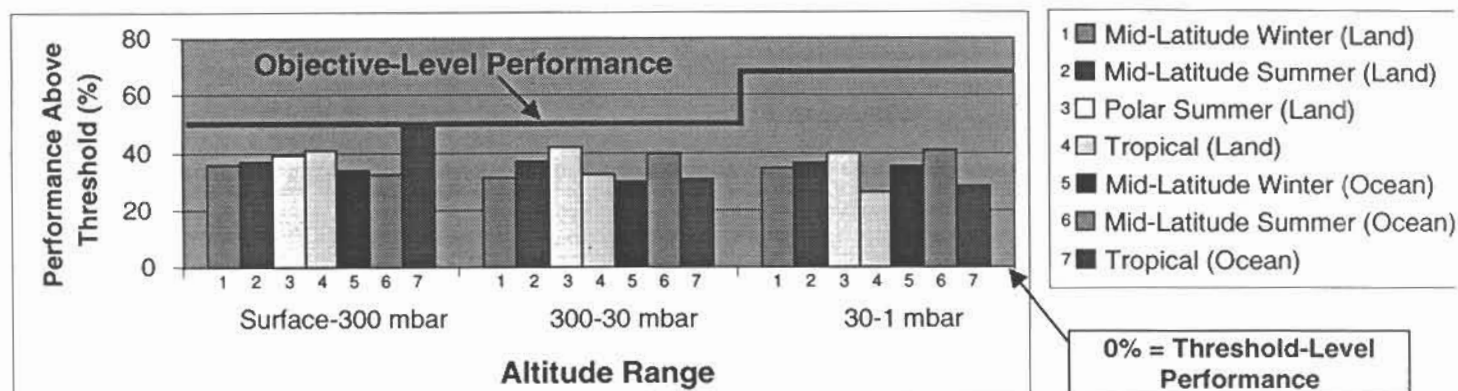
Figure 10. Expected CrIS Temperature EDR Performance for Individual Conditions
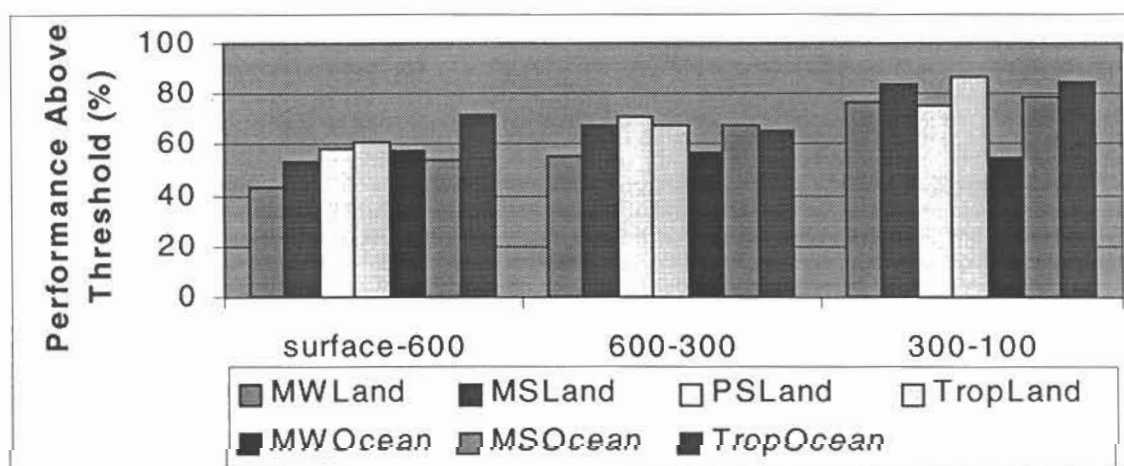
Figure 11. Expected CrIS Moisture EDR Performance for Individual Conditions

7. ACKNOWLEDGEMENTS

THE CROSSTRACK INFRARED SOUNDER (CrIS): DESIGN AND PERFORMANCE

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Cross-Track Infrared Sounder FPA Performance

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Abstract

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) Cross-track Infrared Sounder (CrIS) is an interferometric sensor that measures earth radiances at high spectral resolution, using the data to provide pressure, temperature and moisture profiles of the atmosphere. The pressure, temperature and moisture sounding data are used in weather prediction models that track storms, predict levels of precipitation etc. The CrIS instrument contains SWIR ($\lambda_c \sim 5$ μm at 98K), MWIR ($\lambda_c \sim 9$ μm at 98K) LWIRs ($\lambda_c \sim 16$ μm at 81K) modules. Each module consists of nine large (1000 μm diameter) photovoltaic detectors with accompanying cold preamplifiers. The paper will describe the performance for all the modules forming the CrIS FPA.

Molecular Beam Epitaxy (MBE) is used to grow the appropriate bandgap n-type $Hg_{1-x}Cd_xTe$ on lattice matched CdZnTe. SWIR, MWIR and LWIR 1000 μm diameter detectors have been manufactured using the Lateral Collection Diode (LCD) architecture. Custom pre-amplifiers have been designed to interface with the large SWIR, MWIR and LWIR detectors. The operating temperature is above 78K, permitting the use of passive radiators in spacecraft to cool the detectors. Recently fabricated 1000 μm diameter photovoltaic detectors have the performance listed in the Table below. Expected D* performance from the detector/pre-amplifier models are also listed in the table. The D* values are calculated at the CrIS program peak wavelength specified for each band. Measured FPA performance will be compared to the predicted FPA performance in each spectral band.

	SWIR	MWIR	LWIR
T in K	98	98	81
λ_c in μm	5.02	9.89	15.9
R_oA_{opt} in ohm-cm^2	1.3×10^7	2.0×10^2	9.0×10^{-1}
I_d at $V_d = -0.1$ V	1.0×10^{-11}	5.0×10^{-7}	1.0×10^{-4}
AR-coated QE in %	85	80	75
λ_p in μm	4.64	8.26	14.0
D* in cm Hz$^{1/2}$/W	7.8×10^{10}	1.1×10^{11}	6.9×10^9

Cross-Track Infrared Sounder FPA Design/Performance

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Abstract

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) Cross-track Infrared Sounder (CrIS) is a Fourier Transform interferometric sensor that measures earth radiances at high spectral resolution, using the data to provide pressure, temperature and moisture profiles of the atmosphere. The pressure, temperature and moisture sounding data is used in weather prediction models that track storms, predict levels of precipitation etc. The paper will describe the CrIS detector, pre-amplifier and FPA design. In addition, the measured versus modeled performance will be presented.

The CrIS instrument contains SWIR ($\lambda_c \sim 5$ µm at 98K), MWIR ($\lambda_c \sim 9$ µm at 98K) LWIRs ($\lambda_c \sim 16$ µm at 81K) modules. Molecular Beam Epitaxy (MBE) is used to grow the appropriate bandgap n-type $Hg_{1-x}Cd_xTe$ on lattice matched CdZnTe. SWIR, MWIR and LWIR 1000 µm diameter detectors have been manufactured using the Lateral Collection Diode (LCD) architecture.

Each module consists of nine large (1000 µm diameter) photovoltaic detectors coupled to cold JFET differential source followers. This allows detector specific biasing and impedance matching to the warm electronics. The warm gain stage is configured as an RTIA with a passive T-network in the feedback loop. Closed loop transimpedance values range from $\sim 6 \times 10^3$ for the LWIR band to $\sim 9 \times 10^5$ for the SWIR band. The operating temperature for all colors is above 78K, permitting the use of passive radiators in the spacecraft to cool the detectors.

Recently fabricated 1000 µm diameter photovoltaic detectors have the electrical and optical performance listed in the Table below. Expected D^* performance are calculated from the detector/pre-amplifier models and listed in the table. D^* is calculated at the CrIS program specified peak wavelength values. Measured FPA performance will be compared to the predicted FPA performance in each spectral band.

	SWIR	MWIR	LWIR
T in K	98	98	81
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